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THE

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THE HORSE FOOT CRAB.

BY REV. S. LOCKWOOD, PH. D.

It is proposed to give some results of a summer's study on the incubation of the eggs of the Horse Foot Crab, and to connect those results with observations made in an acquaintance of several years with the animal in its native haunts, in the hope of thereby furnishing something towards a life-history of the species.*

Among systematists this crustacean is known as *Limulus Polyphemus*. It bears also the popular names Horse Foot Crab, Horseshoe, and King Crab. In this article these names will be used as convenience may suggest.

The King Crab delights in moderately deep water, say from two to six fathoms. Except in the case of the very young, which are probably carried thither by the tidal flow;

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*In October, 1869, the writer read a paper before the Zoological section of the New York Lyceum of Natural History, under the title "A Contribution to the Natural History of the King Crab," which contained the notes taken during the summer's investigation alluded to above. The article now appearing in the AMERICAN NATURALIST is taken mainly from that paper.—S. L.

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it never seeks the shallow waters, unless for the purpose of reproduction. It is emphatically a burrowing animal—living literally in the mud, into which it scoops or gouges its way with great facility. The anterior edge of its enormous cephalic shield is not unlike in form the sausage, or mince-meat knife of our kitchens (Pl. 3, Fig. 12). The upper shell of the animal is composed of three parts—the forward shield, which is greatly the larger, the posterior shield, and the long bayonet-shaped spine, or tail. In the burrowing operation the forward edge of the anterior shield is pressed downward, and shoved forward, the two shields being inflected, and the sharp point of the tail presenting the fulcrum as it pierces the mud, while underneath the feet are incessantly active, scratching up and pushing out the earth on both sides. There is a singular economy of force in this excavating action, for the alternate doubling up or inflecting, and straightening out of the two carapaces, with the pushing purchase exerted by the tail, accomplish both digging and subterranean progression. Hence the King Crab is worthy to be called the Marine Mole.

The Limulus is carnivorous. Its food is the soft nereids, or sea worms; so that not only in its mode of burrowing for concealment, but also in its method of procuring food does it resemble that little burrowing mammal of the land. It is sometimes found held in a strange durance, with a limb entrapped between the valves of the quahog, or round clam, (*Venus mercenaria*). It is a pitiful sight to behold—a galley slave with limb confined to ball and chain—"as far from help as limbo is from bliss." The explanation is easy. The quahog too is a burrower, and Limulus has seized the projecting syphon of the mollusc, which being suddenly withdrawn, the less agile claw is jerked between the valves, and the same are closed. This, of course, would effectually entrap the limb. But here occurs just this strange fact, that a lobster or a crab would not long be held in such durance, but would give their custodian leg-bail; that is, would cast off, and desert the imprisoned limb, and in due time would reproduce the lost member.

The position of the mouth, and the masticating process are so peculiar, that a description should not be omitted. The King Crab has six pairs of feet; although by some, those constituting the extreme anterior pair are called antennæ, being greatly shorter than the others. The four pairs between this first pair, and the last pair, have a functional structure differing from the anterior and posterior pairs. Of these four pairs, the basal joint, or haunch, of each limb is flattened and smooth on each side, as though they were a series of plates intended to work upon each other, as the keys of an organ under the fingers of the musician. The external edge of each is rounded, and beveled like the edge of a carpenter's chisel. Thus these flattened haunches lie against each other, their rounded edges directed backward at a considerable angle. The beveled edges (which are the exposed parts) of these projections are covered with very sharp incurved spines, overhanging and pointing into the oral aperture; for it is between these four pairs of spine-clad haunches that the creature's mouth is situated. Each of these basal spines is articulated, and is set in the crater, or cup, of a little teat-like prominence. These then, are the true jaws of the animal's mouth; and as there are four pairs of these manducatory joints, the creature's mouth is set in a line between eight jaws. These spiny teeth have, by their articulation, an amount of mobility in their little pits, which is eminently serviceable and preservative. Of these chewing teeth, though the number is variable, an individual can scarcely have less than one hundred and fifty.

Wishing to see what their food might be, and how they eat it, I placed a specimen, hatched the preceding summer, in a small aquarium, and supplied it with plenty of fresh and tender sea lettuce (*Ulva latissima*). But this sea salad remained untouched, although the young Limulus had no other fare for three weeks. In fact, famishment had rendered it literally diaphanous. I then tried animal food. Having opened a live quahog I routed the little fellow from his hiding place in the sand, and gave it a morsel of the clam. It was ravenous, and fed only as a really hungry being could. Though using the round clam principally, I gave it other food at different times. Any mollusc was acceptable, if only sufficiently tender. It even ate beef; but not with the relish of the mollusca. This I observed, that being well fed it never would eat carrion; although what it would do if impelled by hunger I cannot say.

As yet I had not *seen* the eating. This was also hidden by the carapace. I was now very anxious to witness the feeding process. The first step was to put the animal on a long fast, and thus to secure a good appetite. This done, a bit of clam was dropped before the hungry crab, which was instantly drawn under with its claws, when I immediately turned it over, holding it with the abdomen against the glass side of the tank. It was kept in that position for full five minutes, the eating process being easily witnessed, and the manducation quite satisfactorily observed. The performance is certainly a very curious one. The animal being in its natural position, the food is held immediately under the mouth by the claws, or nippers, of the posterior pair of jawless feet, aided, if necessary, by some of the others. The basal joints, or manducatory haunches, then begin an alternating motion of these members upon the food, by drawing one of the spiny or rasp-like joints against the opposite one of the same pair, the food of course being between the two. This chewing by means of these opposing rasps, reminded me of the hand-carding process, in which the card held by the right hand is brought towards and against the one held in the left hand, the wool being between; when the right hand card is held still, and the left hand duplicates the motion, and so on. The fine particles rasped off by the incurved teeth pass into the mouth. It will be readily seen that food so finely chewed before it passes into the digestive apparatus would afford but a poor chance to the investigator who sought its nature by use of the knife. Of the large number that I have opened of adult specimens, I never found anything to tell me on what they fed; and not until by actual experiment, above described, did I know whether Limulus was vegetarian or carnivorous.

The exuviation of the King Crab is performed several times during the first year, and at very short intervals. How many I do not know, as that must vary according to the time of hatching. But I think the young produced in the latter part of June will accomplish five or six moults before the cold weather comes. Even in the case of the adult — exceptional as it is among the crustacea — I think it probable that the shell is cast more than once in the year. The professional oysterman having taken up his best crop with the tongs, secures the gleaning with heavy iron dredges; and when using this instrument will take up an occasional Horse Foot, even in the winter season. In the unusually fine weather of an open February several years ago, in Rariton Bay, an adult female was in this manner taken out of the mud by the deep sinking dredge, when lo, the animal had but recently "shed," and its shell was still quite soft.

Sometimes the shedding can be witnessed under very unusual circumstances. A large female taken in August, although kept for many days in the open air, yet moulted in captivity. The operation was a very trying one, and required three or four days, as the animal got very dry. A little water was occasionally thrown on it for pity's sake; and even this was not marine water. Of course moulting under such extraordinary circumstances was a very difficult, and probably painful operation; the wonder was that it could be done at all. With natural surroundings a few minutes generally suffice for the task. A thin narrow rim runs round the under side of the anterior portion of the cephalic shield. This is in fact the widest part of the animal. Just before the time for exuviating a separation occurs between this rim, and the perimeter of the anterior shield. To the unaided eye this rent is altogether imperceptible, but opens on the exertions of the animal; and at this opening it emerges from the old shell. Now as the opening is at the front, and in the place of the greatest width, and moreover as the shell is sub-coriaceous, and somewhat yielding, and at this particular place is very thin, it may be seen how great advantage the animal has in this matter over the higher crustaceans whose moult, from necessity, takes place from behind, and whose shell is composed of a more unyielding material. In the exuviation of Limulus I fancy a close likeness to that of the insects when leaving the pupa. The King Crab emerges at the forward, but under side of the cephalic covering; the beetle at the forward, but dorsal side of the same. It is plain that Limulus has an easier time in getting off his old coat than his "more respectable relations" have. To see the King Crab, as it were, coming out of himself, is a sight so odd as to draw from those beholding it the exclamation "it is spewing itself out of its mouth."

When the animal, specially noticed above, had come out of its old shell it was nine and a half inches in the shorter diameter of the cephalic shield; while the vacated shell was but eight inches by the same measurement. If they moult more than once in the year this would make their growth quite rapid; and if they do not, it seems to me that they must attain an age of not less than eight years before reaching the size that indicates adult life. But we must speak of this farther on. I have observed that every spring, that is, so soon as the water has lost its winter temperature, large numbers of the young of the previous summer are found in the shallows. These range from an inch to two and a half inches in the shorter diameter. As the creature when beginning life for itself, is but a scant quarter of an inch in diameter, this would imply rapid growth, and I think that the larger of the above have probably lived through two winters.

There are reasons for believing that the spawn is deposited by the same individual more than once in the same season. I have heard this asserted with confidence by some fishermen. But as they could advance no proof no attention was given it until the following fact occurred. Let me first state that it is a custom prevailing wherever the Horse Foot Crab abounds, to catch it to feed poultry, under the belief that it makes them lay, as it surely does fatten both them and hogs, but imparts a shocking flavor to the flesh of both. The female is always preferred on account of its eggs, of which it has not less than half a pint, crowded within the cephalic shield. These are obtained by inserting the point of a knife into the forward, and under edge of the shield, and running the knife round through the thin rim, already described, when the entire lower part can be torn from the upper part of the shield, thus exposing the eggs, which are like mustard seed, but of an ashy green hue. Now a female that I knew to have spawned in May was in this manner opened in July, and was then to my surprise full of eggs, well formed, and with every appearance of maturity.

The Horse Foot Crab spawns at or near the new and full moon, in the months of May, June and July. By this, however, is only meant that they embrace the time of the extra high tides, which depend so greatly on the lunar influence. But mark the nice calculation herein displayed. They come up at a great high tide, advancing on the bottom, until they reach a suitable spot near to, but within the extreme line of this great tide. Three definite advantages are in this way secured. First, the spawning is performed under water, or without undue exposure; second, the line of the average high tide is thus selected; and third, a short exposure to the daily low tides is thus secured, by which the proper exposure of the spawning spot to the development-accelerating heat of the direct rays of the sun is obtained.

A visit of the adult Limulus to the shore line, except at the spawning season, is a very rare event. At this season they come up in great numbers in pairs; and it may be said with no figure of speech, in true nuptial bands,—the male riding on the shield of the female, and retaining himself firmly in this position by holding to the sides of the posterior carapace, with the two stout and short nipper feet, which are exclusively possessed by the males, which with the size of the animal, so much smaller than the female, serve to distinguish the sex at a glance. The female excavates a depression in the sand, drops her spawn into it, upon which the male emits the fecundating fluid, and the nest is at once deserted, the parents returning seaward, with the retreating tide. Occasionally, a pair less alert than the rest, is left by the tide, which, however, they will overtake, if unmolested. By the action of the water the eggs are immediately covered up with sand; though if the wind be unpropitious, large numbers are often washed up, and cast in windrows on the beach, and soon devoured by the many hungry beings, of bird, fish, and mollusc kind that always abound.

Our Limulus is a true monogamist. But it is likely that a new mate is accepted each spawning time. Occasionally a female comes to shore with even three suitors attached, two of them vainly endeavoring to unseat the accepted one. The above has led to the belief among fishermen of a disproportion of the sexes. I think that this point cannot in that way be inferred.

Though formerly the Horse Foot Crab was very plentiful in Rariton Bay it has become rather scarce. Accordingly they have to be watched for now. Not having the time to spare I engaged a fisherman to keep a lookout in the month of May, 1869, for an actual spawning. He was instructed to see the pair come up and spawn, and to capture them at once on their attempt to return with the tide; he was also told to scoop up with a tin vessel the whole spawn-mass, sand and all, and not to touch the eggs with his hands. I believe the man faithfully obeyed instructions. Thus the spawn and the parents were brought to me uninjured. My preparations had been carefully made. Hatching jars had been set for a number of days, and the water was in a fine state of oxygenation. One difficulty I had to submit to, of a serious character. I could only subject the water to the reflected light of the sun. The direct light would in the summer season prove too warm, and spoil my water. The result, as will appear, was that the hatching was accomplished very slowly, a fact which with another should be borne in mind while reading the following, namely, the absence of those conditions of agitation, variation of water depth, and sometimes complete exposure to air and sunlight, consequent on the tidal flow.

May 26, 1869.—To-day my Limulus eggs were set for hatching. Yesterday was full moon. The eggs were of a greenish white, dull, and rather dirty looking. My notes record no measurement, which I now regret. As incubation progressed the external shell became rapidly darker, and more coriaceous. But for this last fact I had become afraid that they were in process of decay. Several ineffectual efforts were made to get at the internal changes, but owing to imperfect instruments I gave up in despair, and determined to watch and wait for more advanced developments. There is considerable vitality in the King Crab's eggs. It will bear a good deal of retardation, and yet come out at last. It will be understood that necessarily my arrangements had a good deal of retarding effect. At the real amount I was quite surprised. Those on the surface progressed most rapidly.

July 18th.—Thirty-four days after spawning. The opaque chorion has cracked (Pl. 3, Fig. 1) disclosing the white pellucid spherical membrane within. Now a sight met me which gladdened my eyes. It was a living trilobite form. But of course very diminutive. Yet it could be seen with the unaided eye, and quite satisfactorily with a common lens. It is shown greatly magnified (Pl. 3, Fig. 2) in outline. Here the elongate character of the abdominal posterior is noticeable; also the excessive relative width of the thorax.

The figure shows only the upper side, but it has the feet quite advanced, and the two great eyes have well begun. In two or three days it was considerably changed (Pl. 3, Fig. 3). Though not so much, still the cephalo-thorax was relatively greatly in excess of the abdominal shield. The limbs, though not shown in the cut, were quite long, reaching beyond the edges of the carapace. The two sessile eyes were now prominent, but the central oculiform tubercles, as they have been called, but which I prefer to call ocelli, were wanting; for in their place, that is, the central anterior of the cephalic shield, was still a depression, or cleft, yet to be filled up in the progress of development. To me it seems that so far the development was markedly asaphoidal; that is, it reminds me of Asaphus, using that term as the typical genus of the Trilobites. Before passing, it should be observed that the embryo had its two segments inflected; and with short intervals of rest (not many minutes at a time) kept up a very active revolving within its pellucid prison; the effect of this friction on the walls of the hollow sphere would be to bisect it. As the embryo revolves it lies upon its back.

August 3d.—Seventy days from the spawning. To-day an embryo has left the ovum. It measures two and a half lines in length and two lines in width. Except for a little space in front the cephalic shield is armed on its perimeter by a series of briar-like spines, in two rows of about twenty-five each, the spines alternating with some regularity as to size. The curved rim of the pygidium, or caudal shield, is also fringed, but with setaceous tufts, each tuft being made up of hairs of different lengths. This new-born creature is in outline almost circular. The cleft in front of the cephalic shield has disappeared. The sessile eyes are now prominent, and are well up on the shield, the two ocelli are quite distinctly marked. But as yet there is nothing of the articulated tail that marks the parent Limulus, or its congener Eurypterus.

Such was the form (Pl. 3, Fig. 4) of the little being before me. Was it not a veritable trilobite? It at once began to shift for itself, making a persistent effort to burrow like its parent. By consulting the figure it will be seen that besides its tail-less aspect every feature is that of a trilobite. The abdominal, or caudal, carapace is relatively much wider than in the adult Limulus. The segmentary lines afford a very distinct trilobed character to both shields. The spiny and setaceous fringe finds its counterpart in many of the trilobites. The pointed tendency of the keel on the caudal shield seems to me to look towards Pterygotus. But if we take into view the presence of the ocelli already, and the high-up position of the large sessile eyes, we have Eurypterus shadowed forth. Let the reader examine Pl. 3, figs. 5, 6, 7, 8, 9, 10, which give an outline of the telson-plate, or terminal tail-joint of as many separate species of the fossil crustacean *Pterygotus*. Fig. 5 is *P. Banksii*, in which the telson is marked by a cleft. Fig. 6 is *P. bilobus*, showing the cleft less marked, and the presence of a median ridge or keel. Fig. 7 is *P. gigas*, in which the keel is more developed, showing a higher relief, and a greater prolongation, and the disappearance of the cleft. Fig. 8 is *P. Ludensis*. Here the keel is still more acuminated, and the plate itself is mucronated. Fig. 9 is *P. bilobus*, its size being very much reduced. Fig. 10 is *P. acuminatus*. Here the keel has attained an extreme length, and great relief, and is with the plate carried to a slender point. And this prolongation of the telson plate into a terminal spine, is, I think, in respect of posterior development, the highest effort of the Pterygotus. I also think that this is shadowed forth in the embryology of Limulus. But it should be noticed that there is not so far, in all this spinal tendency, anything in the direction of an articulated spine. That is, there is nothing xiphosuroid, or sword-tailed in all this, as in Limulus, and the fossil crustacean Eurypterus, which have an articulated bayonet-shaped appendage. Now Pterygotus has two sessile eyes, and only two, and these are placed low down on the very edges of the forward shield. But Limulus and Eurypterus have both two large sessile eyes set high up on the shield, and two ocelli set forward.

The want of an articulated tail was soon apparent in the case of our little Limulus. The slightest obstacle turns it on its back, when, not having this organ, which the adult uses so effectively in such emergency, the little thing begins a vigorous flapping of the branchial plates. This causes it to rise in the water; then by ceasing the agitation it at once descends, with a chance of alighting right side up. Should it miss the ascent would be repeated until its desire was accomplished.

August 15th.—Eighty-two days from the spawning. A great many had hatched, and many had perished for want of care. I had almost given exclusive attention to the one described above. It had its second moult to-day. A few minutes sufficed for it to withdraw itself from its baby suit. I noticed that it stopped a little while, as if to rest, having the caudal appendage only half withdrawn from the old shell (Pl. 3, Fig. 11). At last out it came, a person of distinction possessing the articulated rapier. It is a true Limulus now, and fully entitled to carry for life, the sword of honor, which has ever been the family mark of rank. The animal is now quite a fourth of an inch in width, and its tail is the one-twentieth of an inch in length. Where did it keep it while in the old dress? It must have been bent under and upon the abdomen. I have noticed them since at this moult, with the tail considerably incurved, and which required some hours to straighten out. Dorsally the little thing has now nearly the complete appearance of the adult Limulus. The setaceous fringe of the abdominal carapace had disappeared, and had left an armature of teat-like or half-developed spines; and the spiny fringe of the cephalic shield was quite gone. The posterior projections of this shield are now sharp. The tail is distinctly articulated, but somewhat stumpy. A section of the adult tail would be almost triangular, the lower side being slightly rounded, the upper sharply edged, while a section of the tail of this young specimen would be almost ovoidal. The tail of the young is also more distinctly marked with lines of segmentation than is that of the adult. As it travelled on the mud before this moult, it made tiny rows of toe-tracks, leaving a plain unmarked space between the rows. Now it moves with tail depressed, and makes a medial line dividing the toe-tracks into two series.

Alas, at this point, when I had become intensely interested, a serious illness, against which I had offered a dogged determination to keep at work, peremptorily settled the matter by taking from me the use of my eyes.

It will be noticed thus far that the observations here recorded, are almost entirely morphological, and not physiological. Professor E. D. Cope has given us a lucid phrase, "expression point." He says of development, "while the change is really progressing, the external features remain unchanged at other than those points, which may be called *expression points*." It seems to me that "expression points" of generic significance have been pointed out four times in these remarks. Twice in the ovum I thought there was an "expression point" of a trilobed genus; and in the larval stage, I thought Pterygotus and Eurypterus were shadowed forth.

And in the metamorphoses of the larval state there are remarkable changes with reference to functional necessities. Already mention has been made of the moult at which the animal receives its articulated tail. Now in the life of Limulus this tail is as indispensable as is the Alpine stock to the Swiss mountaineer. It is constantly liable by the least agitation, or obstruction, to be turned on its back, when but for its tail it would be as helpless as a tortoise in the same position. It is then that it deflects the tail, and inserts this sharp spine into the mud or sand, and after a few persevering efforts succeeds in turning itself over. So feeble are its limbs that exposure of the under side to the attacks of fishes would soon end its career. In short it must keep its carapace "right side up with care," if it would care to live.

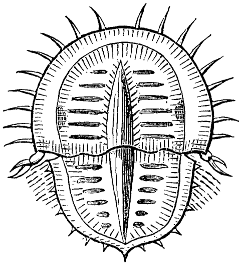
I must now mention another functional metamorphosis which seems to me of a very remarkable character. So great is the difference in form between the anterior feet of the female, and the same feet in the male, that the very children on the shore lines at once in this way distinguish the sexes. In the female this limb is long, slender, and weak; in the male short, stout and ventricose. Intended for strong holding, their nip is like that of a vice. Their use is to hold on to the carapace of the female, so that the male may retain his position as the pair come up in the breeding season. And so strong his hold that no violence of storm, or attack of rival suitors, can displace him. Well does the fisherman know this, as he stands in the water ready to spear the female as she comes up in nuptial embrace. He is only concerned to catch the female, for it would need some force to separate the two. Now functionally, this stout foot, "or hand," as the fishermen call it, has no use in early life. The Horse Foot Crab has its period of puberty; this is its adult stage. But judging from the size of the males when they couple, which is pretty uniform, and their actual rate of growth, I think that the puberty of Limulus cannot come before the third or fourth year. And it would not surprise me if the latter figure should prove the minimum age. However this is the point—it is not until that age of puberty is reached that the male undergoes its last metamorphosis. It then has a moult, from which it emerges, having received its large claws, or literally, its nuptial hands. What change there may be on the emotional side who can tell, when master Limulus assumes the *toga virilis* and is old enough to "propose." This may be asserted of these very decorous and monogamous people, that among them premature marriages are unknown, for however soon the lady may be ready to give her heart, not until maturity of age can the gentleman possibly extend to her his hand.

The above fact was obtained by evidence purely negative, yet not the less convincing. First, there was the suspicion of the fact, then the search for a young male possessing nuptial claws. But albeit the numerical equality of the sexes this was not found, though large numbers of young specimens of different ages were examined. Moreover, I have not found the fisherman who has ever seen one.

Although some of the systematists make of Limulus a distinct order, as *Xiphosura*, or sword-tailed; yet I cannot but think that in nature the Trilobites are included, making of all one grand order. It would thus have not only a real systematic meaning, but a profound chronologic significance. However this may be in the light of coming knowledge, I think Pterygotus and Eurypterus stand higher than the typical Trilobite proper, and that Limulus leads rank over all.

Figure 68 shows Limulus after the first moult (very much enlarged), when not more than a week old. The fringe of the buckler is now less thickly set, the cardinal spines only being conserved, and these not so stout. The posterior shield shows the permanent spines. Still the contour is asaphoidal while the median ridge of the abdominal carapace, terminating in the point of the mucronated shield, is suggestive of the dorsal keel in *Pterygotus gigas* and *P. anglicus*. At this stage, as the facts seem to me, the larval Limulus shows forth more than one generic "expression point" in the career of the trilobite as a "comprehensive type."

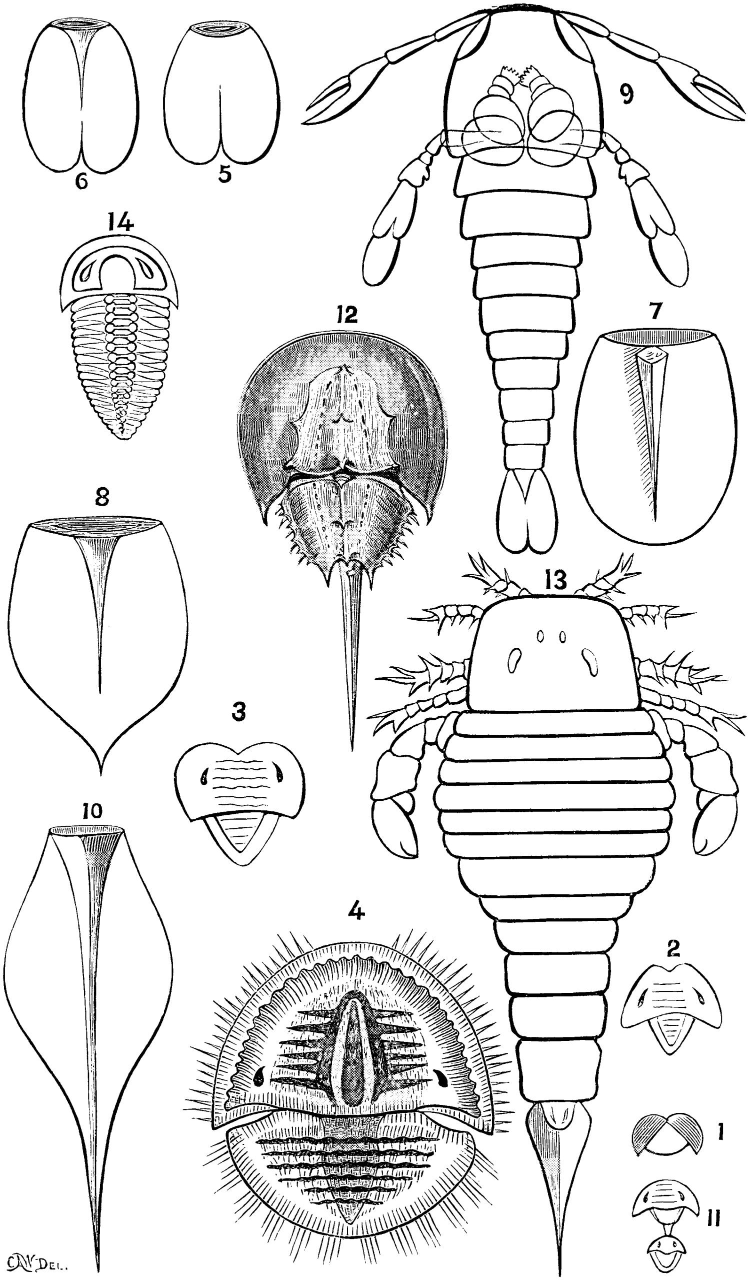
Fig. 68



Limulus after the first moult.

It should be stated here that the exuvia represented by fig. 68 was accidentally discovered on the surface of the mud, at the bottom of an hatching jar, used in these observations last summer. At the close of the warm season last year my jars must have contained not less than two hundred young Limuli. We have already said that so soon as hatched the young burrow like the adult; hence the rareness of an opportunity to witness the casting of the skin. Hoping to continue observations upon the growth of my interesting family the ensuing year the jars were carefully put away. Little regard, however, was paid to temperature, which, on several occasions, went down to the freezing point. On the 3d of May, 1870, I emptied the jars to see how my charge was getting on, when lo, not one of the last year's hatching was alive! but wonderful to say at least a dozen little fellows, all hatched this spring, and all alive, had taken their place. With these were also at least thirty eggs, in different, but all in advanced, stages of incubation. In some of them the young could be plainly seen revolving. The fact was these eggs had been at the bottom of the hatching jar, and had never had any contact with the sunlight. At once, not without some misgiving as to the result, the proper provision was made to complete the incubation, namely, new sea-water, clean sand, the eggs put on top, and all set in a favorable place. With an ordinary hand lens the progress of incubation could be observed daily. At half-past four o'clock on the afternoon of May 11th, before my eyes, a new-born baby Limulus left the egg. Just think of it—these eggs are within two weeks only of being a year old! And then how remarkable are these facts also—those eggs were partly incubated last summer. Hence there has been not only a remarkable retardation of development, but also an actual arrest of the same for seven or eight months without sacrificing life. Query: is there any connection here with that indomitable persistence of being, which in the Divine will has carried this comprehensive type through the many EONS of existence, wherein has been unrolled so slowly the life plan of the Entomostraca, from that initial Trilobite of the Pre-siluria to our Limulus of these latter days?

It has been hinted already in this article that at different stages of its life the larval Limulus made a different impress



LOCKWOOD ON THE HORSE-FOOT CRAB.

when it walked. While tailless there were simply two parallel sets or rows of toe-tracks, but when tailed those parallel rows were separated by a median line, showing the caudal trail. Is there not here a caution for the interpreters of the "Protichnites" seeing that the same species, at diverse ages, may make widely different tracks?

Not more than three or four exuviæ were found entire in the mud of the hatching jars. In all the rest the buckler and the pygidium were separate. Now it is not the case that the Horse Foot shells, in the long wind-rows on the shore-line, are entire. The entire ones are decidedly exceptional. Before certain tides the young are helpless; but the adult never comes shoreward except to spawn. Hence their exuviæ are brought up by the wash and the under-tow of storms, thus effecting the separation of the two parts. Is there not here an explanation of the great abundance of the pygidia, or caudal shields, of the *Asaphus Iowensis* in the Iowa limestone rocks? I do not regard them as the debris of dead trilobites but as their cast-off shells. They are the tidal windrows of that ancient sea. The articulation of the two carapaces was no doubt feeble; and the specific gravity of the pygidium less than that of the buckler. In this case the debris would be sorted into different depths of water. The bucklers would be less crowded, because in greater depths where the tidal action was less; while the lighter pygidia would, by the same law, form the drift of the shore-lines.

EXPLANATION OF PLATE 3.

Fig. 1. Egg of Limulus just cracked by incubation, showing the pellucid sphere.
Fig. 2. Embryo in the egg, much enlarged.
Fig. 3. Same two days older, much enlarged.
Fig. 4. Young Limulus just out of the egg, enlarged nine diameters.
Fig. 5. Terminal tail joint of *Pterygotus Banksii.*
Fig. 6. Terminal tail joint of *Pterygotus bilobus.*
Fig. 7. Terminal tail joint of *Pterygotus gigas.*
Fig. 8. Terminal tail joint of *Pterygotus ludensis.*

Fig. 9. *Pterygotus bilobus.*

Fig. 10. Terminal tail joint of *Pterygotus acuminatus.*

Fig. 11. The smaller one is Limulus just hatched, natural size, mere outline; the larger is the same undergoing the first moult, and leaving the old shell, and having a tail.

Fig. 12. Limulus Polyphemus, one year old. The markings on the posterior carapace become less distinct with adult age. The adult female will attain a size even exceeding twelve inches across the cephalic shield.

Fig. 13. *Eurypterus remipes;* size very much reduced.

Fig. 14. *Sao hirsutus*, a trilobite.

THE SEA-WEEDS AT HOME AND ABROAD.

BY JOHN L. RUSSELL.

THE vegetable productions of the ocean, like those of the drier portions of the earth, are subject to a similar order of distribution. The most common collector of plants becomes soon aware that there are kinds which are not to be looked for in ordinary places, and soon learns to set a value on those which rarely occur to him. He also desires to extend the area of his observations so as to embrace different latitudes, or to obtain the same results by ascending lofty mountain heights. So the collector of sea-weeds does not confine himself to particular districts, but endeavors, either by personal inspection or else through the labor and courtesy of others, to ascertain what forms, seemingly familiar or entirely diverse, may grow abroad. The deeper soundings of the ocean-beds, like the higher elevations of the land, afford him a greater variety, affected by different causes, which in their natural course produce different results.

The general plan of vegetable life, especially in the lower plants, seems to point to constant modification of some one typical form, and this modification appears to have its origin in climatic influences. It becomes a most fascinating study to endeavor to join the separate and divided links so as to